

Makerspaces as a Tool for Science Teacher Preparation

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Despite the now decades-long push for STEM (science, technology, engineering, and mathematics), STEM subjects continue to be taught largely in separate classrooms by different teachers who rarely plan lessons together or coordinate instruction. Separate instructional times for each of the STEM disciplines is still necessary to dive deep into disciplinary knowledge, but outside of traditional schooling, these subjects nearly always overlap to some degree. Students who leave traditional schooling having only experienced each of these disciplines separately often find themselves challenged to apply their learned knowledge to real-world contexts that integrate STEM applications. Further, the siloed nature of STEM education, and thus our STEM knowledge, is perpetuated when we do not prepare science teachers to explore the interdisciplinarity of STEM disciplines and their applications to real-world scenarios.

Makerspaces are collaborative workspaces inside schools, libraries, universities, and independent organizations that provide the tools and facilities for creating, exploring, learning, and inventing—collectively referred to as *making*. Making involves collaborative learning-by-doing and the creation of personally meaningful solutions to authentic problems through iterative design and fabrication (Kjällander et al., 2018; Rodriguez et al., 2018). Maker facilities can range from low-tech (e.g., cardboard or tape) to high-tech (e.g., 3D printing and modeling or coding) tools and materials (Woods & Hsu, 2020), and foci can range from extracurricular STEM exploration for youth to fostering entrepreneurship among adults. Makerspaces typically share a maker mindset that recognizes the importance of flexible thinking, persistence, perceiving mistakes as learning opportunities, and reflection (Rodriguez et al., 2018).

The learning that occurs in makerspaces demonstrates the interdisciplinarity of STEM disciplines (Woods & Hsu, 2020), as well as heavily engages students in the crosscutting concepts (CCCs) of science and the scientific and engineering practices (SEPs), as defined in the *Next Generation Science Standards* (NGSS Lead States, 2013). By prioritizing students' engagement in the CCCs and SEPs, maker activities create intellectual need (Harel, 2013) for disciplinary knowledge that is immediately relevant to a problem that students are invested in solving.

To illustrate this interdisciplinarity, we use two eighth-grade students, Robbie and Harper (pseudonyms), in the second author's maker-based, integrated STEM class as examples. The students in this class use the United Nations' (2022) Sustainable Development Goals (see sdgs.un.org/goals) as inspiration for their projects. Robbie's project, which was inspired

by Goal 14: “Life Below Water” (United Nations, 2022), sought to design, model, and calculate scale for a solar-powered cargo ship that does not contribute to ocean pollution. Robbie used an iterative design thinking model to explore the biology of marine life to identify critical prerequisites for aquatic life, the ecological impact of international trade, solar and battery technology and parameters, and physics concepts to determine buoyancy and material strength. Harper chose to focus on Goal 5: “Gender Equality” (United Nations, 2022) and produced and edited a podcast series that calls middle school students to be civically engaged with issues of gender inequality. Harper’s in-depth research required her to ask questions while seeking additional information, compare arguments, assess the credibility and accuracy of informational sources, organize and analyze data to provide evidence, and integrate the new understanding into focused episodes that explore the history of gender inequality, advocate for gender equality, explore the mental health impacts of inequality, and raise a call to action for middle school students. Through such projects, students pursue solutions to global challenges that directly impact their lives, and as such, they become empowered to be engaged global citizens who seize the opportunity and the responsibility to apply school-learned knowledge to real-world problems.

Although teacher preparation programs may not be able to devote significant time to preparing their graduates to facilitate maker-based learning, we argue that simply engaging teacher candidates in maker-based learning can yield numerous benefits. For example, Blackley et al. (2017) found that engaging in maker experiences allowed preservice teachers to overcome their anxiety about their own lack of science content knowledge and concerns about students asking questions they could not answer. From our experience, engaging inservice teachers in mentored, maker-based instruction allows them to see how it is accomplished and feel less overwhelmed. Through mentored teaching experiences in which a maker educator first leads the instruction while the inservice teachers assist, which is followed by a trading of roles, science teachers realize that although the classroom may seem chaotic and disorganized, students are engaged in goal-directed tasks that compel the meaningful disciplinary learning of science concepts. As such, maker-based learning becomes more approachable, and as Blackley et al. (2017) concluded, teachers experience the value of learning-by-doing as well as enhanced identity development as a science educator.

References

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